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GENERAL REQUIREMENTS OF THE NATIONAL BOARD OF FIRE UNDERWRITERS IN REGARD TO WATER WORKS[1]

By Robt. E. Andrews[2]

The Baltimore conflagration of 1904 was the immediate cause of the entry of the National Board of Fire Underwriters into municipal affairs on a large scale. During the fourteen years previous to that date, a large number of reports on cities had been prepared by single inspectors, usually fire chiefs of long experience, and, as was natural from their training, little space was devoted to water works. The Baltimore fire caused a direct property loss of $50,000,000 and aroused the insurance companies to the possibility of similar fires in other cities.

This conflagration was carefully studied from many angles and the preparation of reports on all the large cities of the United States was begun in a systematic way. Instead of single inspectors the work was carried on by parties composed of engineers specially trained in the branch of the work they were to handle. In addition to description and criticism of water systems, the reports outlined fire departments, fire alarm systems, actual structural conditions and laws and ordinances relating to building and to fire hazards—all leading up to a discussion of the possibility and probability of a conflagration—and followed by recommendations for improving conditions thought to be unsatisfactory.

The engineers preparing these reports were pioneers in a new line. There were no fixed standards by which a water system, or the other features considered, could be judged from the fire protection point of view. What standards there were in regard to these matters, were the results of opinion rather than of experience. That the reports did not go far wrong is shown by the one issued on San Francisco in October, 1905, in which the catastrophe of the following

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[1] Presented at the second annual meeting of the California Section, October 1, 1921.

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April is vividly foretold. This conflagration, with a property loss very greatly exceeding that of Baltimore, again emphasized the importance of the work, and brought home to the insurance companies the immense aggregation of values which can be destroyed by a single fire. Except for the period of the war the issuing of reports on the larger cities of the country has gone on without interruption. Usually about thirty-five reports are published each year. Copies of the printed report are sent to city officials, civic organizations such as Chambers of Commerce, Rotary and Kiwanis Clubs, to newspapers and to influential citizens particularly interested in fire protection.

By 1916 approximately 300 cities had been reported on, some of them three times. The amount of information acquired in the prosecution of this work was enormous. Enough data were on hand so that careful studies could be made of the various features upon which effective fire protection depended. Conditions in one city were compared with those in others of the same class. Conclusions were no longer based on opinion but on the results of many years of experience. If, for example, we asked that a distribution system be composed of mains of certain sizes, it was because thousands of tests had told us that suitable quantities of water for fire protection could not be obtained unless the mains were of the sizes recommended.

In fact, we had so much information in our files and had acquired so much experience in this particular field, that we felt justified in taking an ambitious step forward—namely, grading cities with reference to their fire defences and physical conditions. Up to this time, the work of the National Board of Fire Underwriters had been confined almost entirely to the larger cities. It was felt, however, that any system of grading which might be adopted, should apply equally well to cities and towns of all sizes. Accordingly, an intensive study was made of a large number of small towns and villages, and the standards modified, where necessary, so that all would be considered with equal fairness.

The plan adopted is like that of marking a school-boy's examination paper, where so much is taken off for every mistake. The sum of the maximum points of deficiency totals 5,000 and is divided in accordance with the relative values of the features as follows:

	points
Water supply	1700
Fire department	1500
Fire alarm	550
Police	50
Building laws	200
Hazards	300
Structural conditions	700
Total	5000

That is, a city where the fire defences and physical conditions are excellent would have few points of deficiency, and one where conditions are as bad as possible would approach 5000 points. The water supply is given a weight of about one-third of the total requirements. It is considered as being of slightly more importance than the fire department, as a water system is of some value for fire protection where there is no organized fire department, but a fire department without water is almost helpless. A good water supply in connection with a poor fire department, or vice versa, is obviously of less value than if both are good. In recognition of this fact an equalizing charge is made where the two features differ greatly in efficiency.

The *Grading Schedule* has been received with marked enthusiasm. A number of engineering societies, some of them national in scope, have investigated the schedule and given formal approval. Insurance rating organizations use it for classifying cities and towns in all states of the Union except in Texas, New Jersey, part of Pennsylvania and on the Pacific Coast. Its use for this purpose precludes any possibility of discrimination and allows every town to know in what respect and to what extent its fire defences are deficient. As a guide for outlining improvements for fire protection it is invaluable.

A water works is judged from two view-points, *adequacy* and *reliability*. To be considered adequate, a system must be capable of supplying a reasonable quantity for fire protection for a period of ten hours, in addition to domestic consumption at the maximum daily rate. It is frequently suggested that we ought to base our calculations on the maximum hourly rate instead of the maximum daily rate. We feel, however, that it would be going to the extreme to assume that a serious fire would occur exactly at the peak hour of the highest day. Fires of the magnitude with which we are chiefly concerned ordinarily burn for a longer period than the duration of the peak hour. There is always the possibility that citizens may suspend lawn sprinkling during a large fire and that water works' officials may operate gate valves so as to reduce the flow to parts of the city remote from the fire; both of which would reduce the domestic consumption. Furthermore, pressures are naturally reduced in the vicinity of a large fire, and sometimes the area affected is of sufficient size to cause a noticeable decrease in consumption. For these reasons we think it preferable to use the maximum daily rate.

The quantity asked for fire protection in the central business district, is usually that determined by a formula based on population, which was worked out by Metcalf, Kuichling and Hawley and presented in a paper read before this Association at its annual meeting in 1911.[3] The quantities required are shown in the following table.

POPULATION	REQUIRED FIRE FLOW, GALLONS PER MINUTE FOR AVERAGE CITY	POPULATION	REQUIRED FIRE FLOW, GALLONS PER MINUTE FOR AVERAGE CITY
1,000	1,000	28,000	5,000
2,000	1,500	40,000	6,000
4,000	2,000	60,000	7,000
6,000	2,500	80,000	8,000
10,000	3,000	100,000	9,000
13,000	3,500	125,000	10,000
17,000	4,000	150,000	11,000
22,000	4,500	200,000	12,000

When the population exceeds 200,000 provision should be made for two fires occurring at the same time, and we ask for 12,000 gallons a minute for the larger fire and from 2,000 to 8,000 gallons for the second fire. The total quantity in all cases includes an allowance for loss from broken connections and hydrants left open, incidental to a large fire.

Occasionally the quantity indicated by the formula is modified as required by unusual local conditions. For example, in the vicinity of large cities there are generally suburban communities having good sized populations but with mercantile districts of very small area and without congested construction in comparison to the population. Obviously to require the average fire flow in this case would be unfair. Conversely, there are cities of small population, remote from other cities, which are surrounded by thickly settled rural territories and which are in fact the mercantile center of a population several times that within the municipal limits. Such cities require more than the average fire flow.

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[3] JOURNAL, Proceedings, 1911, p. 55.

The time limit of ten hours required for the fire flow has been determined upon as closely approximating actual needs. Nearly all conflagrations have lasted much longer than this—some of them ten times as long. The use of water, however, begins gradually and increases for several hours as more lines of hose are brought into play. The peak load ordinarily continues several hours and as the fire is brought under control the quantity gradually becomes less. Ten hours of full fire flow probably amounts to the average quantity of actual flow at the variable rate. For towns under 2,500 population the time limit has been reduced to five hours.

In speaking of the fire flow required, I characterized it as being *reasonable.* It is merely the quantity which good practice demands should be available and not that which might be needed under the most extreme conditions. In the Baltimore conflagration water was actually used at the rate of 33,000 gallons a minute, yet in our reports we have asked only that 12,000 gallons a minute should be available about any block in the congested business section, with 6,000 gallons a minute additional for a second fire occurring at the same time. A few months after our report on Hartford, Connecticut, was issued, in 1916, a fire occurred at which water was used at exactly the rate we requested. This fire did not spread outside the building in which it originated, and was very much smaller, so far as water needs are concerned, than other fires which are probable. For four hours during the Atlanta conflagration in 1917 water used on the fire was at the rate of 13,000 gallons a minute, yet the fire occurred in a residential section for which we modestly asked 2,500 gallons a minute about any block. Examples like these could be multiplied indefinitely. If there is any error in the quantities we recommend, I believe it is in not asking enough.

The second viewpoint by which a water system is judged is *reliability.* In general, reliable fire protection requires duplication of such parts of a water system as may reasonably be expected to become inoperative. Aqueducts of good design and of substantial construction, such as masonry or concreted steel, are considered sufficiently dependable as not to require duplication. A paper on the reliability of pumping stations was read by Clarence Goldsmith, an engineer of the National Board of Fire Underwriters, at the 1917 convention of this Association and covers this phase of the subject excellently.[4]

It is recognized that a so-called gravity system—one delivering supply direct to the city from the source without the use of pumps, is preferable from a fire protection standpoint, but a well-designed and properly safeguarded direct pressure system, such as the high pressure fire systems of some of our large cities, so nearly approaches the gravity system in adequacy and reliability that no distinction is made between the two types.

The introduction of storage, either elevated and supplying the distribution system or for suction supply, off-sets to a greater or less degree the need of duplication in various parts of a system, the value of the storage depending upon its amount and location. In general, all storage lessens the requirements of those parts of the system through which the supply has already passed. It is assumed that storage adequate to meet maximum consumption demands for five days plus fire flow for ten hours, is sufficient to permit the making of most of the repairs, alterations or additions incident to the operation of a water supply system. Where storage fluctuates materially during the twenty-four hours, the minimum storage maintained is used in all calculations. In no case is a rate greater than the actual capacity of the mains from the reservoir considered. Owing to the decrease in pressure when water is drawn down in standpipes, only the capacity of the top twenty-five feet is considered as effective storage, unless the standpipe is on elevated ground and fire engines are generally used.

In grading a water system deficiency charges are made under thirty-two separate headings. To describe these in detail would require more time than is available. Briefly stated, however, the principal requirements are as follows:

The chief executive, either superintendent or chief engineer, shall be competent and qualified by experience. Employees shall not be subject to removal by every incoming political administration. Records and plans shall be such as to facilitate repairs and to permit the efficient operation of the system. Emergency crews shall be quickly available. Fire alarms, particularly in direct pressure systems, shall sound in appropriate water works quarters.

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[4] JOURNAL, December, 1917, p. 432.

Two items are of fundamental importance and may have very heavy charges. The first is based on the normal ability of the source of supply, including impounding reservoirs, and all parts of the supply works, to deliver the required quantity to the district being considered. The second is the reliability of the source of supply. Under supply works we include intakes, suction lines, pumps, boilers, stacks, air compressors, filters and force or supply mains. The extent of deficiency of each part of the supply works is considered and the percentage of deficiency of the most serious is used for computing the charge. Under reliability we consider such items as frequency and duration of droughts, physical condition of intakes, danger from earthquakes, floods, forest and grass fires, ice dams and other ice formations, and silting up or shifting of channels.

Pumping capacity must be such as to allow two pumps in reserve. The deficiency charge, however, is very small for the second reserve unit and is still further reduced for small cities. In cases where both low-lift and high-lift pumps are provided and reliability of supply is dependent on both, they are considered separately, and, if necessary, charges are made for each. Boiler capacity with a reserve of one-fourth the entire capacity, and in any case at least one boiler, must be sufficient to operate the pumps and auxiliaries required. Electric transmission lines, steam piping, or gas or oil piping to internal combustion engines or boilers, shall be so arranged that a failure in any line, or the renewal of a valve, transformer or oil pump, would not prevent maintaining, in connection with storage, maximum domestic consumption for two days and fire flow for ten hours. Pumping stations and other portions of the plant shall contain no combustible material in their construction, shall be protected from exposures and have suitable private fire protection. When pumps are electrically operated the generating station supplying them should have the same features of reliability that are required in the pumping station.

Although aqueducts of substantial construction are not required to be duplicated, suction or gravity lines to pumping stations, flow lines from reservoirs, force mains, etc. shall be of such capacity and so laid out that no single break will prevent the delivery of the required quantity. Such lines shall be laid as not to endanger each other, and their failure at stream crossings, railroad crossings and other points where physical conditions are unsatisfactory shall be guarded against. In connection with supply mains, there must be arteries and secondary feeders of sufficient size extending throughout the distribution system. The gridiron shall be made up of minor distributors, 6 inches or larger in diameter, connected at intervals not exceeding 600 feet and free from dead ends. These charges, however, are reduced where pressures are high. In other words, it is a certain quantity of water that is wanted, rather than a strict adherence to a rule. Pipe in unreliable condition, whether cement-lined, wood or metal, is charged for.

The distribution system shall be equipped with a sufficient number of gate valves so located that no single case of accident, breakage or repair to the pipe system will necessitate the shutting from service a length of pipe greater than 500 feet in high value districts, or greater than 800 feet in other sections.

The requirements for hydrant spacing are based on the assumption that hose lines shall not exceed 500 feet in length when laid directly from hydrants, and 600 feet in length when supplied by fire engines. The unit of measurement which has been adopted for determining hydrant spacing is the area served by each. The area required depends on the quantity of water which the fire department may be called upon to handle. In the largest cities the average area served by a hydrant in the congested district shall not exceed 40,000 square feet, but in villages where a fire flow of only 1,000 gallons a minute is asked for, an average area of 120,000 square feet is permissible. Hydrants shall be maintained in good operative condition, shall be of such size and type as to deliver 600 gallons a minute with a friction loss of not over 2½ pounds, and connections to mains shall be gated.

I imagine some of you will say it is well to aim high. I admit that our standards are high, but they are by no means unattainable. The very fact that so many water systems approach complete compliance shows that our requirements are not excessive. Of sixteen cities on the Pacific Coast, on which the National Board of Fire Underwriters have recently issued reports, three have water works which may be considered as 90 per cent perfect from the standpoint of fire protection. One grades as high as 95 per cent. And in this state, where so many of the water systems are designed for abnormally high consumption and are capable of meeting the maximum hourly rate, the margin available for fire-fighting is unusually large. As compared with other sections of the country the typical California system is decidedly superior.